International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 12 | Dec 2018 www.irjet.net p-ISSN: 2395-0072

A STUDY ON USE OF BUILDING INFORMATION MODELLING FOR COST ESTIMATION PROCESS

R Mahadevi[1], N Manodeepan[2], CT Saminathan[3]

[1,2]Assistant Professor, Department of Civil Engineering, The Kavery Engineering College, Tamilnadu, India
[3]Final year student, M.E. Construction Management, The Kavery Engineering College, Tamilnadu, India

---

Abstract - *Cost estimation plays a vital role in project cost management by taking right decisions at the right time. It is extremely important for any project team to develop accurate cost estimates to prepare for bidding and to deliver the projects on time, within budget and with high quality. Cost estimation is an integral part of construction management process and its accuracy can influence downstream processes, analysis and decisions. It is a more difficult process and highly error prone, especially, due to project complexities.*

The growth of construction industry is highly reliable on the recent advancements of new technologies and their adoption. Currently, the construction industry moves from traditional CAD to BIM process to make the construction processes more efficient and robust. BIM (Building Information Modelling) is a new model-based approach that increasingly captivated the focus of the construction industry. It facilitates generating up-to-date cost estimate directly from 3D digital model without involving any manual calculations. With BIM, it is possible to modernize cost estimation process to minimise the cost and time over-runs in the projects.

This study helps to understand the benefits of moving from a document-centric approach to a data-driven approach and it provide insights on use of BIM with guidelines, workflow, process and approaches for cost estimation in the construction projects.

Key Words: Cost Estimation, BIM Application, 5D Model, Cost Modelling

1. INTRODUCTION

India's economic growth heavily depends on the construction industry since it contributes third highest share to nation's economy. There are quite a few challenges being confronted during the delivery of construction projects these days such as schedule delays, cost over-runs and quality issues and they are due to lack of innovation, automation, technologies and use of recent advancements in the construction industry. Construction industry still has lot of space for improvement in terms of embracing latest technologies so that it can catch up with other developed industries such as manufacturing and banking.

The successful project always fulfils the client expectations such as high quality, within stipulated time and within an agreed budget. There are numerous causes for cost over-runs and schedule delays such as scope creeps, changed site conditions, under estimation of cost etc.,

Construction industry needs to decide the selling price even before construction gets started but whereas other industries fix the selling price after production. So, construction project is highly risky, and its success purely depends on accuracy of cost estimates. The project team needs to sensibly decide the price through bidding process as overpricing leads to missed opportunities and underpricing leads to less profit or a significant loss.

Quantity take-off is a manual process which involves measuring different design elements from various drawings, specifications and arriving at the quantities of various elements in the building and it is based on interpretation and experience of the cost estimation professional. So, this approach has high chances of error. 2D based documents are developed by hand or with CAD tools. Manual approach multiplies any errors present in original drawings. Furthermore, it is very hard to find the relationship between the different elements from 2D drawings.

Traditional cost estimation is labour intensive task as it involves manual take-offs from various 2D construction documents. When there are changes in the inputs, updating the cost estimates by manual approach would be difficult and time consuming since it needs manual calculation to be performed again for the changes.

Cost estimates are required in every stage of the project for various purposes and they will be prepared an average of seven times in project lifecycle. Cost estimates would be helpful to make all cost related decisions whether to make an investment or not. This provides baseline budget to accomplish for monetary objectives and probable earnings from the successful delivery of the construction project. More importantly, it allows construction team to explore various possibilities with feasible alternatives in early stages of the project to utilize value engineering concepts.

The BIM use is rapidly growing in construction management streams especially in cost estimation process to develop up-to-date and more accurate cost estimates directly from digital model with the available project information. The use of BIM for developing cost estimates would minimise the efforts and time and increase the accuracy.

Cost estimation is yet another aspect of the building process that can benefit from computable building information. By using a building information model instead of drawings, the takeoffs, counts, and measurements can be generated directly from the underlying model. Therefore, the information is always consistent with the design [1].

BIM based cost estimation is very efficient and robust since the changes made in the design i.e. in 3D digital model then, the changes would automatically reflect in all the associated construction documents such as drawings, and schedules. The time spent on preparing estimates is predominantly quantity take-off and it is approximately about 50 to 80% in conventional approaches. There is a greater potential to achieve huge time savings through use of BIM in cost estimation process.

2. COST ESTIMATON

Cost estimation is the process of calculating the predictable resource costs to finish specific tasks of the project. The project requirements advance when project progresses, and it is always difficult to develop 100% accurate estimate due to limited availability of information. Of course, it is an iterative process and needs to be done numerous times with latest information to get more reliable and accurate estimate as and when required.

The accuracy highly depends on the information used for developing the cost estimates such as design, specification and drawings. It is primarily referring to expected cost from concept to commissioning but not unexpected costs.

This is very next logical step which takes place after the project planning phase of the project. Project plan and cost estimate are key elements for providing a safe environment for construction team to achieve all project goals.

Steps involved in cost estimation process are as follows:

Fig -1: Cost estimation process (Devised by the author based on the literature)

The following figure depicts the relation between cost estimate accuracy and time phases of the project. The estimation error will be more and less in initial and advance stage of the project phases based on the availability of project information at that instance.

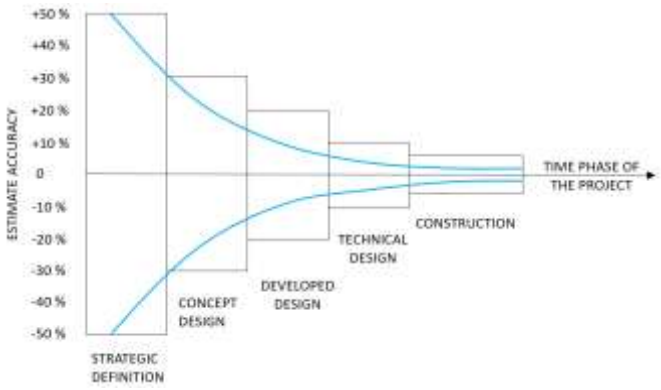


Fig -2: Relationship between time and estimate accuracy

(Devised by the author based on the literature)

Factors affecting the cost estimation results are listed down below:

1. Completeness of input information
2. Quality or accuracy of input information
3. Constructability
4. Construction methods
5. Site conditions
6. Size and nature of construction
7. Location
8. Complexity

Many types of cost estimates are available in the construction industry based on the project phase and purpose. More detailed and accurate estimates are expensive and will be needed in the advanced stage of the project.

Types of cost estimates (based on accuracy):

- Conventional estimate
- Detailed estimate

2.1 Importance of cost estimates

The cost estimation also supports the management objective of estimate accuracy, reasonableness and project risk through the summary of report and analysis.

Construction cost estimation is the process of identifying and compiling many items of cost that will enter a construction project [2].

Cost estimates are quite useful in different construction activities of the project such as:

- To provide information for client to make investment decision,
- To make purchase/procurement decisions for materials and equipments,
- To carry out the resource planning activities in the material planning, personnel/man power planning, equipment planning and cost planning,
- To prepare time and efforts estimate with the quantities,
- To identify the cost variation due to change orders
- To provide information for making future cost decisions,
- To provide information for making payments for contractor on completed works,
- To provide information for cost management or cost control of the project,
- To assess financial performance of the project,
- To compare the base line and actual cost to know profit/loss from the project, and
- To avoid cost over-runs and schedule delays of the project.

2.2 Inefficiencies in traditional cost estimation process

No cost estimation tools available in the construction industry meets all the expectations and they are continually evolving to meet the growing needs of cost estimation requirements. There are numerous inefficiencies in the current methods and systems although computers are being utilized for cost estimation process.

In 2D environment, it is very difficult to develop accurate cost estimate since one has to refer multiple input information such as design, specification and drawings. Any changes in the drawings would need updates in quantity take-off and cost estimates. It involves a lot of attention to carefully go through all the changes through revision clouds marked in the drawings and manually revise the quantities and cost estimates.

BIM would help to integrate all the elements of the building with logical relationship and it can recognize the change very easily from digital model. It automatically updates all the outputs i.e. construction documents such as drawings, schedules, quantities and cost estimates that relate to 3D model with no time.

There are more chances of error during digitalization and it can produce inaccurate quantities and cost estimates. Digitalization is a very easy process but doing it in large scale is practically difficult since it is a semi-automated process.

The interpretation skills of the cost estimation professional decide quality and accuracy of the cost estimates in traditional method for quantity take-off. Manual efforts are needed to provide inputs of the parametric data from CAD file such as Length, Width and Height into calculate the quantities for calculating costs.

Errors in quantity and cost estimates may arise in the cost estimate process, such as forms of arithmetic errors (addition, subtraction, or multiplication), transposition errors (errors in copying quantities), omission (overlooking parts of the design), poor references (scaling from papers instead of using the dimensions indicated), and unrealistic waste factors [3].

Cost estimate results are affected by complexity of the project. The accuracy of the cost estimates is more when they are prepared for simple projects. And, it is less when they are prepared for complex projects due to understanding difficulties and lack of computation power for complex geometries.

3. BUILDING INFORMATION MODELLING

Referring to the National Building Information Model Standard (NBIMS), BIM is defined as “a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward” [4].

BIM is a multi-dimensional prototype of built environment with valuable information such as physical, time, cost, facility management, sustainability information etc., BIM helps to minimise the construction errors since it adopts virtual design and construction concept wherein the facility is built twice. Once virtually in 3D environment before even construction gets commenced and second at site. This new model approach ensures what fits in the model will fit at site and aids constructability of the project. BIM process allows to collaborate and communicate well with all project parties to deliver highly coordinated project by integrating all the disciplines. BIM is both technology and process change which transforms the way we do the things.

With BIM, it is possible for the users to develop, manage, store and retrieve the digital database which allow all the project parties to provide their inputs in early stages of the project lifecycle. This would help project team to perform

interference checks to ensure high level of coordination between different departments or disciplines through seamless collaboration.

Application of BIM in cost estimation is very beneficial when it involves complex calculations or a lot of repetitive works to be performed for finding out the most accurate estimates. It is one of the unexplored areas of BIM which can reduce significant efforts and time of cost estimation so that they can do some useful activities rather than counting the number of objects manually such as: value engineering, interference checking, constructability reviews, etc.,

3.1 BIM maturity levels

When we talk about BIM use, we must talk about BIM maturity level since it is important for anyone to understand what's the scope for BIM use in their projects. Maturity level helps us to find the level of BIM use or level of information exchange in the project with guidance and supporting standards. There are four different levels of BIM use commonly available in the construction industry.

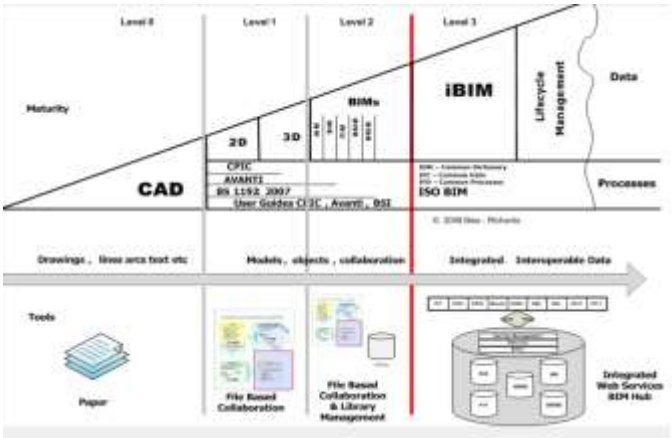
The British Standards Institute (BSI) has adopted a useful maturity model developed by Bew and Richards which illustrates that BIM practice can cover a broad spectrum. [5].

Level 0 – Unmanaged CAD,

Level 1 – Managed CAD in 2D or 3D format,

Level 2 (Lonely BIM) - Managed 3D environment held in separate discipline "BIM" tools, and

Level 3 (Social or Integrated BIM) - Fully open process and data integration enabled by "web services" compliant with the emerging IFC/IFD standards, managed by a collaborative model server.



(source: https://www.cdbb.cam.ac.uk/Resources/ResoucePublications/BISBIMstrategyReport.pdf)

Fig -3: BIM maturity levels [5]

Currently, level 2 BIM is mandated by government in most of the developed countries for all the government projects. This would encourage the construction companies to use BIM in their projects. Level 2 BIM is the most ideal point for starting BIM journey to enjoy the benefits of the digital construction.

3.2 BIM dimensions

A BIM model is more than a 3d model and is now a multi-dimensional model. Whenever a specific information type is provided into the model then different dimension is set. BIM dimensions are connected to the type of data that can become available through the process.

Different types of BIM dimensions are as follows:

3D: refers to geometry.

4D: refers to time data.

5D: refers to cost data.

6D: refers to sustainability.

7D: refers to life cycle management of a building.

It would be useful to give the time and cost information in the digital model during cost estimation process so that we can multiply the cost information with estimated quantities to get cost estimate. Time information shall be used as guide to decide the number of resources that are needed to complete the activities.

Based on the time information, cost calculations can be performed separately for resources, and templates can be configured in BIM software applications to arrive the total cost from the unit cost and estimated quantities. The profits, overheads and risks can be added on top of calculated cost to meet any unforeseen contingencies.

3.3 BIM level of development

Level of development (LOD) is a very fundamental concept used in all BIM projects to define the content and reliability of BIM elements in various stages of the project. Very minimal information is needed at the initial stage of the project and maximum/detailed information is needed in the construction stage of the project. LOD is expressed in numbers. Increase in number indicates the model elements have more content and reliable information.

LOD100 – Concept,

LOD200 – Design development,

LOD300 – Documentation,

LOD400 – Construction and

LOD500 – Facilities management.

(source: https://www.tekla.com/image/lod100-400-1800pxjpg)

Fig -4: BIM level of development

Conceptual estimates and detailed estimates can be prepared from LOD100 and LOD400 BIM models respectively. The level of development plays a vital role in preparing cost estimates based on BIM models. More accurate and detailed estimates need more elements or contents and reliability. The BIM models can be developed with appropriate contents and reliability based on the purpose of the cost estimate. The BIM model needs to be sufficiently detailed to prepare cost estimates.

3.4 BIM approaches for cost estimation

BIM based cost estimation is a very easy and simple process since it directly provides the quantities of the building elements from digital model. It doesn't completely automate the cost estimation process since the software applications are continually evolving. The currently available software applications are predominantly helpful in estimation the quantities from the model. Use of BIM for cost estimation provides some basic information which may be useful to get more accurate cost estimates. The accuracy of the cost estimates purely depends on the level of development and dimensions of the model.

It won't be always possible to wait until the end of design phase to develop cost estimate. Interim estimates can be prepared to evaluate various design options to see the most feasible options. Since, it is important to analyse the design options before design is complete to avoid the cancelation of project or applying value engineering concepts. It is very difficult or not possible to link all the cost database of the building elements with BIM models. Cost estimation in BIM environment is very effective as it directly provides the quantities and cost information which are needed to prepare cost estimates. The current capability of BIM software helps automating the cost estimation process with the following options in addition to instant quantity take-off.

3.4.1 Output to Excel

Currently available BIM software applications can produce building object quantities and it can be exported in different formats. Widely used format for quantity take-off is MS Excel. The simplicity and control are best suited for cost estimation workflows. This would enable cost estimation professional to proceed with developing cost estimates by linking the exported quantities and cost database in spreadsheet or some other estimation software. There should be a way to establish a link between BIM outputs and cost database to make this process more robust. The optimised cost estimation results can be achieved by embracing best modelling practices and techniques.

3.4.2 Application programming interface/Direct link with estimation software

This approach is very simple since BIM design tools have direct link with BIM estimation software through plug-ins or add-ons. The outputs of BIM design tools such as Revit can be directly imported as input in BIM estimation software such as Tocoman iLink so that it helps to analyse the model contents, create excel reports and fully automating the cost estimation process. Model visualization shall be provided with BIM design tools in Navisworks to facilitate cost estimation and scheduling process. This direct link between the software applications can simplify the design changes in the construction projects. Whenever the building design changes, BIM estimation tool updates the cost estimates in no time and it is much easier than using current 2D methods. It increases the productivity in terms of quantity and cost management from sketches till completion of the project.

3.4.3 ODBC link

This approach typically uses the ODBC (Open database connectivity) to access the attribute information in the building model, and then uses exported 2D or 3D CAD files to access the dimensional data. The part of the integration includes a reconstitution of the building data within the costing solution – linking cost geometry, attributes, and pricing [1].

This approach is very similar to the previous approach and only difference is that they can support with features that allow both automated and manual extraction of quantities. BIM design tools can export the models in specific formats and they can be imported as inputs in this specialized estimation software such as Vico, Cost X. This software would be helpful to visualise the models and their components in different colours and import the quantities directly from digital model by linking with cost database to proceed with cost estimation process. Even these tools can be used without BIM design tool models, the excel sheet quantities can be used as inputs to prepare the cost estimates by associating the excel output with cost database. These software tools preserve the assembly levels and the items which are linked which would be useful in cost estimation process. This is very simple approach since it doesn't need any BIM knowledge to work on specialized BIM estimation software tools.

3.4.4 Using customized user defined attributes

This is a new approach which shall be used for calculating the cost estimates based on the unit price without involving much complex calculations and, with a very few cost

components so that the unit cost shall be directly multiplied by estimated quantities to get the cost estimate. The author suggests adding a few cost components as user defined attributes or identity data parameters in BIM software applications to provide inputs on cost information for building objects such as labour cost, material cost, equipment cost, processing cost, inventory cost and other costs. Total unit cost can be calculated by summing up all the above said cost elements. To develop the cost estimates, the total unit cost shall be multiplied with quantities and this can be exported in MS Excel format.

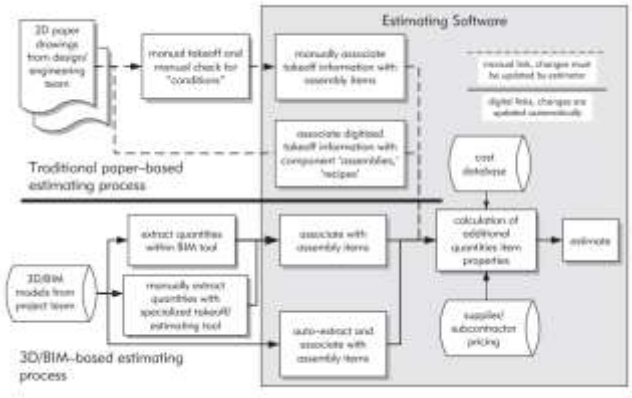


Fig -5: Conceptual diagram of a BIM quantity takeoff and estimation process [6]

3.5. Interoperability

Different project stakeholders use different software applications and construction projects involve multiple disciplines such as mechanical, plumbing, electrical, geo technical, structures, architecture, landscape etc., All the models need to be federated to see the coordination between the disciplines and find out the interferences. BIM platform provides the inputs for coordination issues and see how they are mitigated to resolve the conflicts or clashes between the models. Interoperability is defined as the ability to exchange the information and handle in propriety formats.

AEC industry strongly believes that BIM is the most widely accepted methods of collaborating and communicating the information with the project stakeholders. There is also a data drop between different stages of the project and it leads to discontinuous flow of information. The duplication of efforts is needed to develop the model from scratch if interoperability doesn't exceed. Interoperability allows the models from upstream shall be used in downstream to save the modelling efforts. For instance, structural analysis model from Etabs or Staad can be used in Revit or Tekla to come up with drawings and produce quantity take-off.

It facilitates project parties to use best of the breed BIM software applications and allows to exchange in the information in the most efficient way. There are three different ways widely adopted to exchange the information between BIM software applications such as:

- Bi-directional link between software applications,
- Using API and
- Using proprietary formats such as IFC, DWG etc.,

3.6. BIM training

Trainings can be organized regularly across the organisation to improve the BIM competency amongst the employees. Skill matrix must be prepared and maintained to categorize the employees based on their expertise in BIM. Trainings can support the new beginners to start their career with BIM environment. The training needs assessment should be carried out properly before conducting for training and effectiveness of the training should also be evaluated. On the job trainings, workshops, seminars shall be organized to create knowledge pool in BIM software applications. More than software, training needs to be imparted on the process and workflow to remove the barriers of BIM implementation.

Enhancing the knowledge and skills that are needed to meet the current and future requirements shall be done only through BIM trainings. The success rate of achieving the BIM benefits is highly relies on training. So, it is very important to rollout BIM training and awareness programs across the organisation. Trainings would help developing BIM capabilities and deliver projects in BIM environment. It also provides opportunities to win new projects in BIM environment.

3.7 BIM benefits

The benefits of BIM have better control on the cost, time, quality, health and safety, communication and collaboration. Application of BIM in the construction projects provides wide range of benefits and some of them which are more relevant for cost estimation are listed below:

- Quick quantity takeoff
- Faster and more effective process
- Better visualization and decision making
- Effective change management
- Greater Collaboration
- Reduced rework, conflicts and errors and
- Minimized risk

3.8. BIM barriers

Without any doubts, application of BIM for cost estimation has several benefits in the construction project. As BIM is in growing stage, there are quite a few challenges in the BIM implementation for cost estimation such as:

- Ownership and responsibility
- Collaboration and teaming
- Implementation issues
- Cultural resistance
- Poor quality models
- Interoperability issues
- Set up costs and training
- Legal and contractual risks

4. CONCLUSIONS

The BIM acceptance across construction industry is continuing apace. This study reveals many areas in BIM that is believed by construction professionals to be more effective than conventional means of cost estimation. Construction projects are getting more difficult and complex these days due to ever-increasing needs of clients. Embracing BIM in construction projects is to build competitive advantage and deliver precise cost estimates that allow contractors to prepare bids, plan for resources and control the cost in the construction project.

This study makes an attempt to provide good understanding in the application of BIM software applications for cost estimation to enhance the effectiveness and efficiency levels in construction project.

Cost estimation in BIM environment would contribute to deliver better built environment and achieve cost savings for the country by greatly improving the construction efficiency. It brings transformation in the construction industry through innovative approach to avoid the wasteful processes and inefficiencies and pay due regards to other engineering areas such as lean management, effective construction management and value engineering.

With BIM, it is possible to quickly extract accurate quantities of construction resources and cost estimates directly from 3D models in the project and use them effectively in any stage of project lifecycle. It would help preparing more reliable cost estimates and derisking the construction processes through elimination of the monetary losses and schedule delays because of underestimation.

REFERENCES

[1] Autodesk Building Industry Solutions (2007), "BIM and Cost Estimating", White paper, accessed: 2007. http://images.autodesk.com/apac_grtrchina_main/files/aec_customer_story_en_v9.pdf

[2] Kalpit N. Patel and Harold M. Tepper (1990), "Construction Cost Estimating in Project Management", The New Jersey Institute of Technology, PP 1-3.

[3] Daniel W. Halpin and Bolivar A. Senior (2006), “Construction Management", Second Edition, John Wiley & Sons, Hoboken, NJ.

[4] BIM Industry Working Group UK (2011), "A report for the Government Construction Client Group".

[5] National BIM Standards, NBIMS, "BIM Definition, accessed: 2018

http://www.nationalbimstandard.org/faqs#faq1

[6] Charles M. Eastman, Chuck Eastman, Paul Teicholz, Rafael Sacks, Kathleen Liston (2011), "BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors", Second Edition, John Wiley & Sons, Hoboken, NJ.